Research on Computer Aided Urban Space Environment Design

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Abstract. With the speeding up of urbanization process and the improvement, the importance of urban space environment design is becoming increasingly prominent, and the requirement of urban space environment design is also more and more high. Big data has become an important direction of social development and research focus, playing a positive role in various fields. Aiming at the shortcomings of traditional urban spatial environment design, this paper, aiming at the actual needs of urban spatial environment design. Meanwhile, it can make up for the deficiency of the traditional GIS spatial decision model in process simulation ability. The paper also builds a dynamic urban land expansion model that can describe the interaction between agents affecting urban land expansion. Under the constraints of multiple objectives, the paper carries out simulation and analysis of urban space environment design and application research to help understand and solve the relevant unstructured problems encountered in the process of urban planning. It provides advanced technology methods and reference for promoting urban sustainable development decision-making.

Keywords: Computer Aided; Urban Space; Environmental Design
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1 INTRODUCTION

In the 21st century, mankind is facing great challenges to the sustainable development of global environment and global society. The global environment is changing at an unprecedented speed, and a series of major global environmental problems have posed a serious threat to the survival and development of mankind. The contemporary climate challenge is changing the mindset of architects, which has sparked broader interest. Guo and Wang [1] validated the modeling steps and the evaluation method for reasonable routing through examples. Practical applications have proven that computer sculpture modeling methods have strong practicality for the concept of 3D software modeling in art design. The new development of artificial intelligence (AI) and ubiquitous digital technology has brought inspiration to emerging intelligent cities. Traditional site analysis inevitably faces problems such as a lack of sufficient quantitative analysis, excessive subjectivity, and difficulty in processing large amounts of data and information. The "3S" technology, including geographic information system GIS, global positioning system GPS, and remote sensing technology RS, is a technical system that automatically collects, monitors, and assists decision-making on the infrastructure and land use status of cities. The application of "3S" technology can achieve efficient collection, processing, and analysis of information required for design [2]. Lallawmzuali and Pal [3] input the data collected by GIS into the computer in the form of data. By using OpenGL, three-dimensional views can be obtained, and terrain and landforms can be realistically presented. This technology greatly facilitates designers and expands their thinking space at the three-dimensional level. Inspired designers, while reducing a lot of repetitive work, the rationality and scientificity of the design are more scientifically guaranteed, and the design cycle is shortened. Liu et al [4] analyzed the mainly reflected in the interaction between humans and computers, which is increasingly evident in the creation of digital models and multimedia performance. Urban spatial system is a complex system.

Ng and Chan [5] examined the composite solid results of students dissecting 2D shapes and volumes using 3D CAD using a design-based research method. Analyzed the various comprehensive STEM learning practices they presented in the activity. Niu [6] conducted a comprehensive study in environmental art teaching using computer-aided design, starting from the actual teaching process. Guided by this concept, the specific curriculum makes the reform of training methods for environmental art majors the core of environmental art majors. Large-scale strategy has become increasingly important for its large-scale production. Patin O et al. [7] reported the large-scale production simulation. Quan et al. [8] developed an digital landscape is a highly simulated model that combines a system with computer software and hardware systems. Its spatial evolution is characterized by a large number of micro-behavioral agents (enterprises, residents, farmers and various organizations, etc.) with initiative and adaptability, as well as nonlinear interaction between behavioral agents and environment, resulting in discontinuous urban spatial decision-making behaviors. Traditional urban space design mainly relies on empirical analysis and mathematical model to analyze and manage the urbanization process, but lacks spatial analysis of the urbanization process. S É Dzicki et al. [9] utilized computer-aided design software to analyze and design plants landscape effect. Through visualization technology, various elements of landscape design are presented in a graphical manner, making it easier for designers to choose and design. Choose suitable plant species and configuration methods, and configure plants reasonably to achieve the best landscape effect. Utilize artificial intelligence technology to analyze and optimize various elements of landscape design. Although cities account for only 2% of land area, the activities of people living in cities account for 78% of total CO emissions and contribute to three-quarters of the world's pollutants. Stojanovski et al. [10] proposed issues related to the application of artificial intelligence and generation algorithms in digital urban design practices. Urban Information Modeling (CIM) is an emerging urban design theory and method aimed at providing better support and guidance for urban planning, design, and management by simulating the complex system of a city. Integrating Urban morphology and design theory into CIM can help urban designers better understand the complexity of cities and improve the scientificity and feasibility of urban planning and design. Tong et al. [11] aim to model and design cities through parameterization methods, in order to better understand the complexity of cities and improve the scientificity and feasibility of urban design. Collect relevant data on urban terrain, landforms, buildings, roads, greenery, etc., and preprocess the data to better simulate the complexity of the city. Using parameterization methods to model cities, parameterize various elements of the city, and input the parameterized data into the model to achieve parameterized modeling of the city. Analyze and optimize the model, including simulating urban transportation, water resources, and other systems, evaluating and optimizing urban design plans to better guide urban design. Finally, the model is applied to actual urban design, and designed and optimized based on the actual situation of the city to achieve the best urban design effect. Willis et al. [12] introduced the Fusion 360 Gallery. This dataset was generated from designs submitted by CAD software package users to Autodesk Online Gallery. This dataset provides valuable data that can be used to learn about personnel's design methods, including sequential CAD design data, design segmentation based on modeling operations, and design hierarchy and connectivity data. In the landscape architecture industry, computer-aided software is used by landscape designers due to its accuracy, speed, and comfort characteristics. Make it an excellent practice in interior decoration, advertising design, and urban planning. Xu and Wang [13] introduced different software to understand their advantages and disadvantages, and introduced the current status of landscape design and landscape design processes. Zhang and Deng [14] emphasized the artistic technique of organically combining colors, light and shadow, plants, and other landscape elements to create a unique and expressive landscape. Here are some suggestions for artistic combinations of landscape colors. Zhou et al. [15] believe that parameterized computer-aided design for urban information modeling is an emerging urban design method that can help urban designers better understand the complexity of cities. Improve the scientificity and feasibility of urban design, and make greater contributions to the sustainable development and beautiful future of the city.

Combining them with the basic problems of urban spatial decision-making may reveal the mechanism of urbanization process to a large extent, and greatly improve the ability of GIS analysis and simulation of spatio-temporal process. Based on this background, this paper presents a multi-agent based urban land expansion model for the actual needs of urban spatial environment design and combined with the multi-agent system theory. Through quantitative simulation analysis of specific problems in regional urban spatial design, it helps to understand and solve the relevant unstructured problems encountered in the process of urban planning. The paper is divided into four chapters. Chapter 1 mainly introduces the necessity of urban space environment design and chapter arrangement. Chapter 2 mainly studies the main methods and effects of urban spatial environment design. Chapter 3 is based on the multi-agent land expansion algorithm modeling, and introduces the multi-agent mechanism to realize the urban spatial environment development estimation. Chapter 4 mainly uses the designed expansion algorithm to model the urban area of a city, and evaluates the effectiveness of the algorithm. Chapter 5 is a summary of the work of the full text, and the next step of the work proposed.

2 STATE OF THE ART

As a complex dynamic system, the spatial evolution of city not only involves natural factors, but also is affected by various social and human factors. Although GIS can better solve some urban planning spatial analysis problems, it can only provide static analysis tools, and has great limitations in process modeling. It is difficult to simulate and explain complex urban spatial phenomena, and it is difficult to fully analyze the mutual influence between individuals in urban micro-space and clearly express their decision-making behaviors. Therefore, coupling bottom-up multi-agent system in GIS to construct urban intelligent spatial decision-making model will greatly enhance the ability of existing GIS to analyze urban complex spatial system and make up for the deficiency of current GIS's weak ability to analyze the evolution process of urban spatial system. Therefore, it can provide useful decision support for improving the rationality and scientificity of urban planning spatial decision and promoting urban sustainable development.

Intelligent agent has three meanings: one is a person who can be responsible for his behavior; Something that is active in a physical, chemical or biological sense and capable of producing an effect, and an agent, which accepts a commission from someone and performs a function on his behalf. From the perspective of knowledge processing, agents are active computing units that have certain knowledge and can effectively use knowledge to solve problems for specific goals. From the perspective of social intelligence of multi-agent system, Agent is such a process, it can only do some simple things without thinking, but when these agents are formed into a society by some specific methods, real intelligence will be generated.

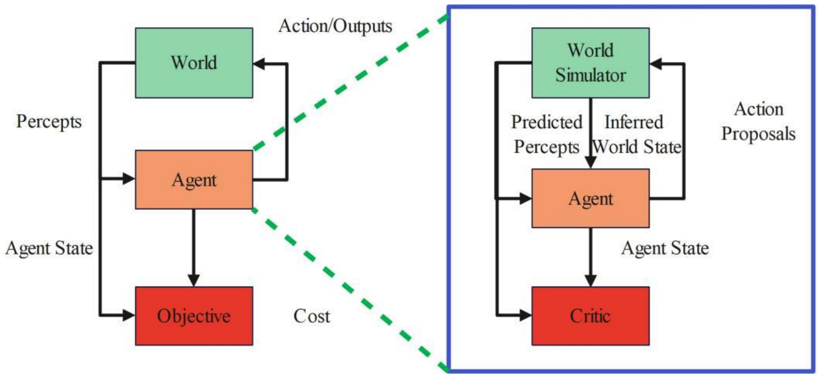

Figure 1: Agent in the environment.

Figure 1 shows an abstract view of an agent. In this block diagram, you can see the action output of the agent in order to influence its environment. In an environment of moderate complexity, agents cannot fully control their environment, but at most can only partially control, that is, have an impact on the environment. From an agent's perspective, this means that performing the same action twice in the same environment can have a completely different effect. Many agents can live together in an environment, and each agent can actively and autonomously act. Their behavior is the result of their own perception, reasoning, decision, and interaction with other agents and environment.

Multi-agent system adopts bottom-up modeling idea, which is different from the traditional bottom-up modeling idea. Its core idea is to study how local detail changes highlight complex global behaviors through the cyclic feedback and correction between local detail models reflecting individual structural functions and global representations. The relationship between individual and whole in a multi-agent system.

3 METHODOLOGY

3.1 Multi-Agent Urban Land Expansion Model

Figure 2 uses spatial entity represents the external environment in which the Agent lives. The Agent is affected by the external environment and will also act on the external environment to change its state. The social environment includes urban land expansion drivers and multi-agent systems (MAS). Driven by the driving force of urban land expansion, various agents in MAS will directly or indirectly change the state of land use. Due to the complex driving forces of urban land expansion, the driving forces can be divided into external driving factors and internal driving factors according to the design of the model. The external driving factors include economy, population, government behavior and other factors, while the urban land expansion caused by other sudden factors and historical and cultural reasons will not be considered for the time being. Internal driving factors mainly consider terrain, traffic, neighborhood, location and other factors.

3.2 Model Agent and Its Decision Rules

Model Agent is a computational model used to simulate autonomous agents or collective entities. To understand the behavior and interactions of an organization or group, as well as the factors that control its outcomes. Individual subjects are usually described as bounded rationality, and are assumed to act according to their own interests, such as reproduction, economic interests or social status, using heuristics or simple decision-making rules. The decision rules in the model agent are used to describe the decision-making methods of the model agent when facing different situations.

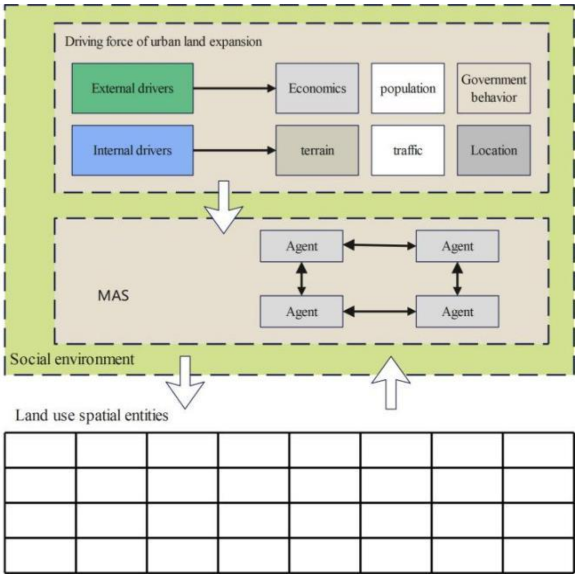

Figure 2: Multi-agent urban land expansion model framework.

Common decision rules include heuristics, templates, random walk and Bayesian learning. Firstly, the spatial distribution of agricultural suitability and urban development suitability of land use unit was obtained through.

$$P_D = P_C / (P_C + P_A) \tag{1}$$

The land use unit x at time t can be regarded as the suitability S of unit x at time t to land use type K, the influence N of surrounding land units on the transformation of unit x into land use type K at time t and the result of the comprehensive influence of random interference factor V, which can be expressed as

$$P_x^k = f(S_x^k, N_x^k, V) \tag{2}$$

Further, for the purpose of calculation, equation (2) can be expressed as

$$P_x^k = ((1+S_x^k)\times(1+N_x^k))^t V \tag{3}$$

$$\max_Q \sum_{t=1}^{n} (aq - bq^2/2 - cq)/(1+r)^{t-1} + \lambda(Q - \sum_{t=1}^{n} q_t) \tag{4}$$

Resident Agent is the process of urban land expansion by choosing the right location as the residence. The resident Agent generates a probability of whether to consider relocation every 1-2 years. If it decides to relocate, it needs to establish the location utility of some candidate regions generated by its search to determine the final relocation place. At time t, for the resident Agent living at place i, the location utility at place j is expressed as:

$$U = \alpha C + \beta L + \gamma E + u_{ij} \tag{5}$$

$$\alpha + \beta + \gamma = 1 \tag{6}$$

Where, C is the traffic accessibility at j after standardization, L is the land value at j after standardization, E is the environmental value at j after standardization, α, β and γ are the preference weights, and u is the random disturbance term of the utility equation. At time t, the probability that unit x is selected by resident Agent as residential land is:

$$ {}^{t}P_{x} = \frac{\exp(u^{t}U_{x})}{\sum_{m}\exp(u^{t}U_{x})} \tag{7} $$

Urban land expansion will lead to the conversion. In this process, farmer Agent does not want to lose the agricultural land he has been living on, so the land near the city and the traffic artery will be converted to urban land first. Better quality, less accessible, protected agricultural land is less likely to be converted to urban land.:

$$ y = a + b_1h_1 + b_2h_2 +, \cdots, + b_nh_n \tag{8} $$

$$ y = \log(\frac{{}^{t}Q_{x}}{1-{}^{t}Q_{x}}) = \log it({}^{t}Q_{x}) \tag{9} $$

$$ {}^{t}Q_{x} = \frac{e^{y}}{1+e^{y}} \tag{10} $$

4 RESULT ANALYSIS AND DISCUSSION

4.1 Experimental Area and Use Data

Urban electronic map (including school, hospital, bank, residential, commercial, industrial and other thematic information), city benchmark land price map, urban digital elevation model, etc. Social and economic statistical data are mainly obtained from the Municipal Bureau of Statistics, the municipal Statistical Yearbook for 2000-2020 and the sixth census data, including urban population statistics, industrial and agricultural output value, urban residents' income, farmers' income, etc.

4.2 Model Realization Process and Parameter Determination

Assuming that each newly added urbanization grid accommodates an Agent, the details can be summarized as the following 5 steps.

1) Determine agents required by the model in different periods according to the formula and use Montocarlo method to generate and farmer in proportion.

2) According to the simulated distribution of farmer Agent, the distance variables and neighborhood variables affecting the decision-making of farmer Agent were determined by combining the logistic regression model, and the probability of converting agricultural land into urban land was calculated.

4.3 Experimental Data and Analysis

The centralized learning algorithm MASAC and decentralized learning algorithm SAC are compared in the collaborative environment CC, and the rewards obtained by the agent in the training process are shown in Figure 3. In the environment, the agent trained a total of 25,000 rounds. As shown in Figure 3, MASAC has reached a state of convergence after training 5000 rounds, while SAC gradually becomes stable after training 17,000 rounds. Both the convergence effect of the algorithm and the reward obtained by the agent, the centralized learning algorithm MASAC is superior to the decentralized learning algorithm SAC.

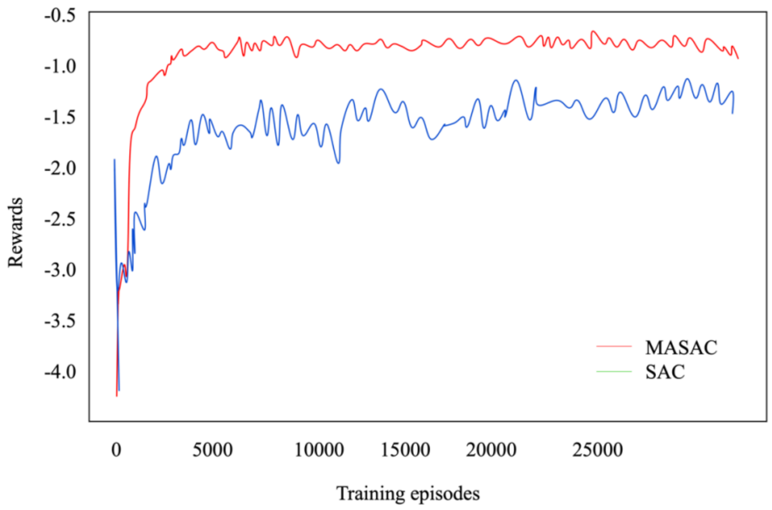

Figure 3: Rewards obtained by different algorithms in the environment.

Different algorithms were used to train the urban space environment design methods of multi-agents, including Mfdr-ctde algorithm, IDQN algorithm and MVEDQL algorithm. There is no Dueling DQN, preferred experiential replay algorithm (Mfdr-ctde-1) and the algorithm with the same fusion weight for all agents (Mdr-ctde) to make intelligent anti-jamming decision under the same interference environment. The average energy efficiency curve of each algorithm changes with the number of training rounds is obtained. The result after smoothing is shown in Figure 4.

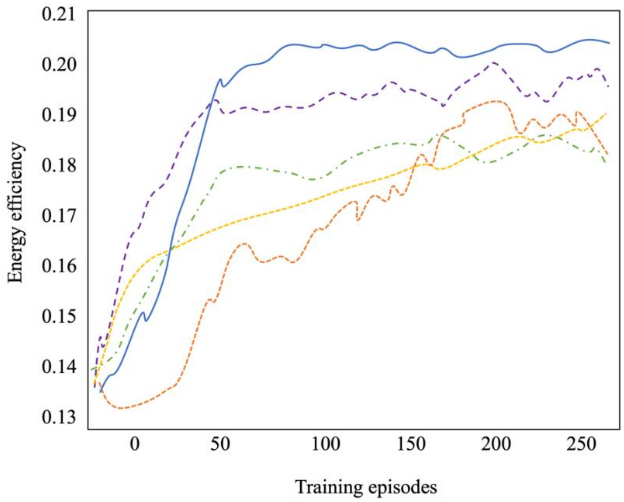

Figure 4: Performance comparison diagram of various algorithms under different training times.

The traditional gravity model method is used to simulate the total urban land expansion, and the simulation results are compared with the multi-agent model, as shown in Figure 5. It can be seen from the figure that the ratio error of most streets simulated by multi-agent is smaller than that simulated by gravity model, and the total accuracy of multi-agent simulation reaches 77.4%, which is significantly higher than that of gravity model simulation (62.4%).

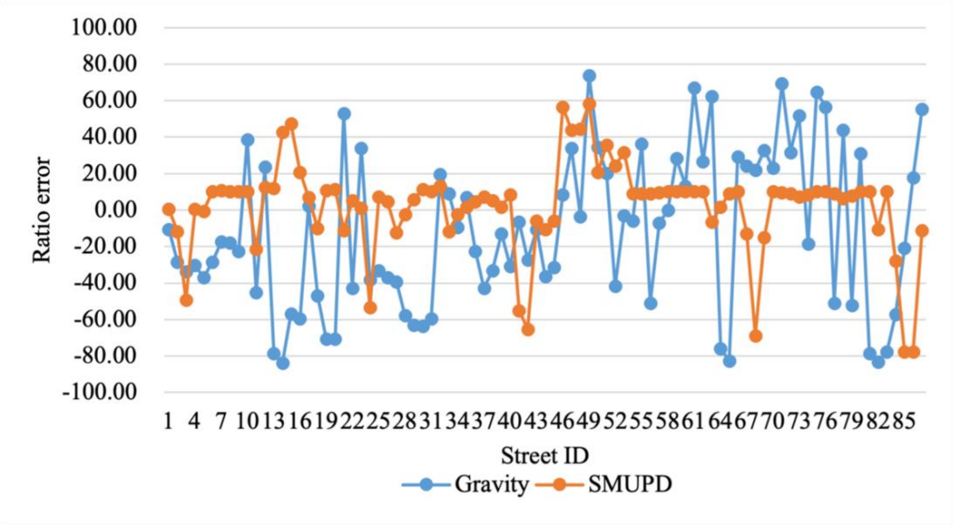

Figure 5: Simulation ratio error distribution between gravity model and multi-agent model.

However, it should be noted that the accuracy of remote sensing classification should also be considered in the real evaluation of simulation accuracy, and a simple evaluation method is presented here (Figure 6).

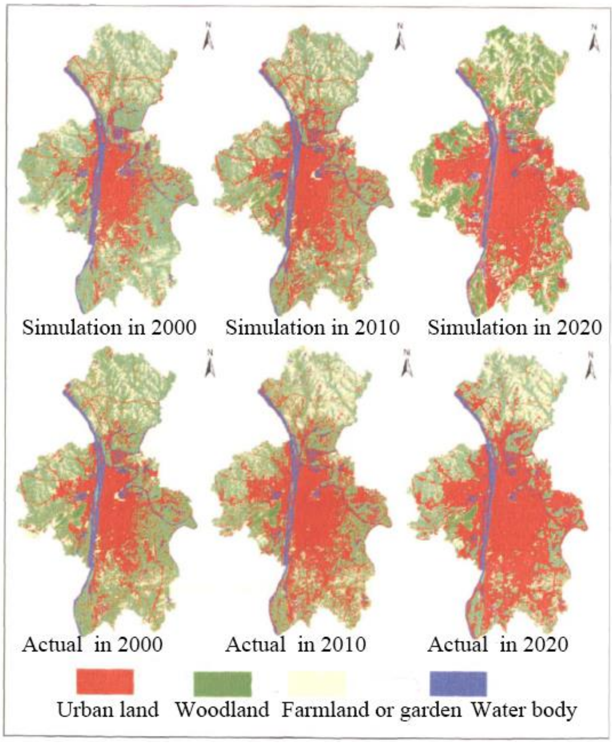

Figure 6: Comparison between simulation results and actual situation.

In the model, the 2010 city street population density data is used to carry out spatial reconstruction of the 2010 city population distribution, and the running results are compared with the actual situation to verify the applicability of the model. Based on the standard of digital population model, the population density simulation data and actual situation data of each plot in 2010 were exported in text format one by one, and the statistics were carried out in SPSS. The prediction result of population density of a single plot was taken as the accuracy standard of more than or equal to 80%. There were 16,260 plots in urban residential areas. The relative error of 13,206 plots was less than 20%, and the overall prediction accuracy reached 81.22%. This shows that the precision of the multi-agent population distribution simulation model is acceptable (Figure 7).

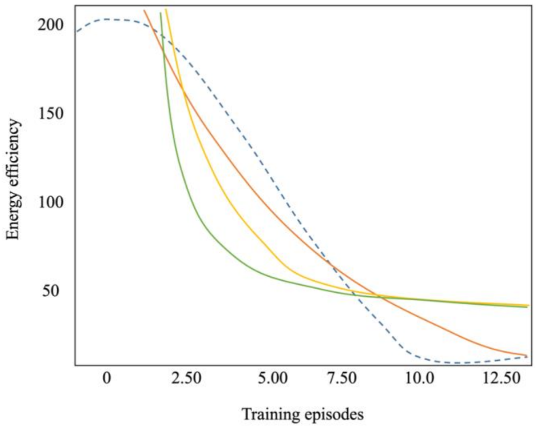

Figure 7: Fitting of multi-agent population density distribution model.

In addition, the radar map is used to compare the pattern of urban spatial growth. With CBD as the center, the simulated construction land in 2010 and the actual construction land in 2010 are counted in 16 directions, and the area of construction land in each direction can be obtained, and the azimuth radar map of construction land expansion can be drawn accordingly (Figure 8).It can be seen from Ray's figure that the distribution of simulated construction land is in good agreement with the actual construction land layout.

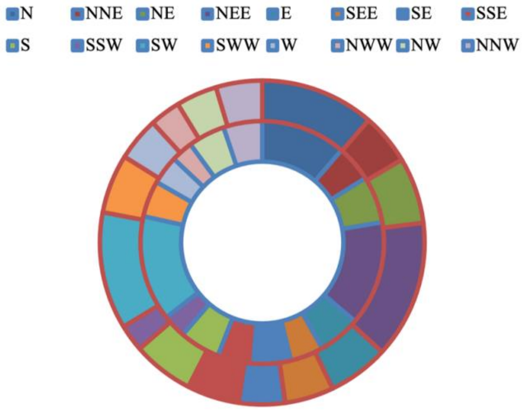

Figure 8: Radar map of simulation results and actual conditions of urban construction land.

5 CONCLUSION

In the field of urban and regional science, many scholars are increasingly aware that the traditional research methods and technical means are unable to effectively solve the problems in the space system such as nonlinear, multi-level, multi-scale, self-organization, self-adaptation, self-similarity, criticality, mutability, and so on, and that new theories and methods are urgently needed to support. This study studies the process and mechanism of urban space complex system with the theory and method of complexity science, regards urban space system as a complex space system, faces the actual needs of urban planning, and tries to combine the theory and technology. To construct an urban space design model that can clearly express the spatial-temporal dominant characteristics of the participants in the decision-making of urban space environment, and through quantitative simulation analysis of specific problems in the design of regional urban space environment, help to understand and solve the relevant unstructured problems encountered in the process of urban planning, so as to improve the scientific and rational decision-making of urban planning space. This paper provides reference for promoting the sustainable development of Chinese cities.

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REFERENCES

[1] Guo, S.; Wang, B.: Application of computer aided modeling design in the expression techniques of sculpture art space, Computer-Aided Design and Applications, 19(S3), 2021, 1-12. https://doi.org/10.14733/cadaps.2022.s3.1-12

[2] Jia, J.: Computer-Aided Design Method of Parametric Model for Landscape Planning, Computer-Aided Design and Applications, 19(S3), 2022, 55-64. https://doi.org/10.14733/cadaps.2022.S3.55-64

[3] Lallawmzuali, R.; Pal, A.-K.: Computer Aided Design and Drafting in Landscape Architecture, Current Journal of Applied Science and Technology, 42(5), 2023, 1-11. https://doi.org/10.9734/cjast/2023/v42i54066

[4] Liu, C.; Lin, M.; Rauf, H.-L.; Shareef, S.-S.: Parameter simulation of multidimensional urban landscape design based on nonlinear theory, Nonlinear Engineering, 10(1), 2021, 583-591. https://doi.org/10.1515/nleng-2021-0049

[5] Ng, O.-L.; Chan, T.: Learning as Making: Using 3D computer‐aided design to enhance the learning of shape and space in STEM‐integrated ways, British Journal of Educational Technology, 50(1), 2019, 294-308. https://doi.org/10.1111/bjet.12643

[6] Niu, F.: Communicative image expression in teaching of computer-aided design for environmental art major, Computer-Aided Design and Applications, 18(2), 2021, 25-35. https://doi.org/10.14733/cadaps.2021.S2.25-35

[7] Patiño, R.-D.-A.; Meramo, H.-S.-I.; Mehrvar, M.; Rehmann, L.; Quiñones, B.-E.; González, D.-A.-D.; Herrera, A.: Environmental and Exergetic Analysis of Large-Scale Production of Citric Acid-Coated Magnetite Nanoparticles via Computer-Aided Process Engineering Tools, ACS omega, 6(5), 2021, 3644-3658. https://doi.org/10.1021/acsomega.0c05184

[8] Quan, S.-J.; Park, J.; Economou, A.; Lee, S.: Artificial intelligence-aided design: Smart design for sustainable city development, Environment and Planning B: Urban Analytics and City Science, 46(8), 2019, 1581-1599. https://doi.org/10.1177/2399808319867946

[9] Sędzicki, D.; Cudzik, J.; Bonenberg, W.; Nyka, L.: Computer-Aided Automated Greenery Design—Towards a Green BIM, Sustainability, 14(14), 2022, 8927. https://doi.org/10.3390/su14148927

[10] Stojanovski, T.; Partanen, J.; Samuels, I.; Sanders, P.; Peters, C.: City information modelling (CIM) and digitizing urban design practices, Built Environment, 46(4), 2020, 637-646. https://doi.org/10.2148/benv.46.4.637

[11] Tong, Z.; Yang, H.; Liu, C.; Xu, T.; Xu, S.: Quantification of the openness of urban external space through urban section, Geo-spatial Information Science, 23(4), 2022, 316-326. https://doi.org/10.1080/10095020.2020.1846464
[12] Willis, K.-D.-D.; Pu, Y.; Luo, J.; Chu, H.; Du, T.; Lambourne, J.-G.; Matusik, W.: Fusion 360 gallery: A dataset and environment for programmatic cad construction from human design sequences, ACM Transactions on Graphics (TOG), 40(4), 2021, 1-24. https://doi.org/10.1145/3450626.3459818
[13] Xu, F.; Wang, Y.: Color effect of low-cost plant landscape design under computer-aided collaborative design system, Computer-Aided Design and Applications, 19(S3), 2021, 23-32. https://doi.org/10.14733/cadaps.2022.S3.23-32
[14] Zhang, M.; Deng, X.: Color effect of landscape architecture design under computer aided collaborative design system, Computer-Aided Design and Applications, 19(S3), 2021, 13-22. https://doi.org/10.14733/cadaps.2022.S3.13-22
[15] Zhou, J.; Phadnis, V.; Olechowski, A.: Analysis of designer emotions in collaborative and traditional computer-aided design, Journal of Mechanical Design, 143(2), 2021, 021401. https://doi.org/10.1115/1.4047685